TECHNICAL REPORT NO. LWL-CR-03P63

POSITION LOCATOR

Final Report
Contract No. DA-18-001-AMC-945(X)

By
Ford Instrument Company
Division of Sperry Rand Corporation
31-10 Thomson Avenue
Long Island City, New York 11101

July 1968

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U. S. ARMY LIMITED WAR LABORATORY
Aberdeen Proving Ground, Maryland 21005

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ABSTRACT

This document describes the design, development, manufacture, and field evaluation of five identical prototypes of a man-carried land navigation system. The unit, known as the Position Locator, provides the user with precise knowledge of his present position in standard Army UMT coordinates (meters).

The five units developed during this program each weigh 10 pounds, occupy 212 cubic inches, and have a battery life exceeding 40 hours. In numerous tests performed in the laboratory and at the customer's facility, accuracies in the order of 1% were achieved.

SECTION 1

INTRODUCTION

1.1 GENERAL

New military tactics and the growing emphasis on limited action and guerrilla warfare increase the responsibility of the individual soldier to know his own precise position and be able to pinpoint for command the locations of subordinate units and target areas. The Limited War Laboratory has supported a number of programs to develop a small, lightweight navigational system to be used by ground forces personnel. Under Contract DA-18-001-AMC-945(X), Ford Instrument Company has developed such an instrument. This final report describes the effort under this program together with conclusions and recommendations for further refinements.

1.2 OBJECTIVES

The primary objective of this program was to develop a portable personnel navigation instrument that would weigh less than 10 pounds, have a battery life exceeding 40 hours, and maintain an accuracy of indicated position within ± 1% plus 10 meters of actual distance traveled. The deliverable items stipulated by the contract included four engineering prototypes and one spare unit, a narrated 16-mm color film, documentation sufficient to enable manufacture by a competent vendor, and an operation and maintenance manual.

The program also included a review of two preceding programs, selection of low-cost components, limited environmental tests, and assistance during field tests at the customer's site.

1.3 CONCLUSIONS

In general, the objectives of the program have been met. Five operational units were delivered to the Limited War Laboratory, were field tested there, and were shipped to Vietnam for extensive field evaluation. While the weight of each delivered unit was 10.6 pounds, changes in the computer housing (which have been incorporated into the documentation) will reduce the weight of any future models to less than 10 pounds. Battery life under normal usage far exceeds the required 40 hours.

Accuracy data based on numerous tests under a variety of conditions, and with experienced operators carrying an assortment of combat gear (rifle, ammunition, radio, etc.), have been in the neighborhood of one to two percent.

1.4 RECOMMENDATIONS

On the basis of the field tests conducted by the Limited War Laboratory, it is anticipated that the field evaluation in Vietnam will confirm the practicality of the Position Locator and demonstrate its usefulness in combat operation. In its present design form, the Position Locator can be supplied in large quantities. However, experience gained during the development program has suggested a number of areas in which product improvement can greatly increase reliability, materially reduce manufacturing costs, and provide further weight reduction. It is therefore recommended that this program be followed by a product improvement phase to implement these ideas and lead to type classification of the Position Locator.

SECTION 2

GENERAL DISCUSSION

2.1 BACKGROUND

For years a military requirement has existed for an accurate means of land navigation by the combat soldier. Land navigation techniques such as pacing and terrain recognition have been developed to a high degree, but they are still limited by poor visibility, inadequate maps, featureless terrains, etc., and place added burdents on the combat individual. Past attempts to mechanize this process have been unsuccessful.

Ford Instrument Company, in cooperation with the U.S. Army Limited War Laboratory at Aberdeen, Maryland, has developed an effective instrument, called the Position Locator, that satisfies this requirement. The overall development effort and the results of the latest of three programs, which has culminated in the manufacture of the five units now undergoing field evaluation in Vietnam, are described in this final report.

2.2 PREVIOUS PROGRAMS

Under contracts DA-18-001-AMC-286(X) and DA-18-001-AMC-286(X) Mod 2 with the Limited War Laboratory, Ford Instrument Company designed an instrument which served as a test vehicle for a number of land navigation studies. The initial program suggested step-length determination based on pedometric and body acceleration measurements. During the Mod 2 program, extensive tests were performed on military personnel to determine their average step length, step-length deviations from the average, and body accelerations, all as functions of different terrains (flat, grass, road, hill, and sand) under daytime and nighttime conditions. The promise exhibited by the results of these two programs led the Limited War Laboratory to support the fabrication of engineering prototypes worthy of field evaluation in Vietnam.

2.3 INITIAL STUDY PHASE

The initial effort under this contract concerned itself primarily with a careful analysis of the two previous programs, in order to establish the optimum approach. It was concluded that the slight improvement in accuracy provided by measurement of body acceleration over that determined by pure pedometric means did not justify the additional complexity. Other significant considerations led to repackaging of the resolving compass in a conical configuration, designing for minimum current drain, designing of an inertial switch, and investigation to find a suitable battery source.

2.4 CHARACTERISTICS

2.4.1 Operational Features. The following are some of the outstanding features of the Position Locator:

- All-terrain all-weather navigation
- Portability
- Lightness
- Silence and nonradiation
- Accuracy
- Continuous position readout
- Nonjamability
- Minimum training requirements
- Mission planning simplification
- Ruggedness
- No warm-up requirement
- No auxiliary equipment requirement

2.4.2 Specifications. The following are the leading particulars of the Position Locator:

Dimensions	
Display unit	1 x 3 x 4 inches
Computer unit	3-1/2 x 7-3/4 x 7-3/8 inches
Weight	10 pounds total
Battery life	40 hours minimum
Temperature range	-10° to 125°F

2.4.3 Applications. Some of the more obvious uses of the Position Locator are as follows:

- Land navigation
- Reconnaissance
- Field grouping
- Target location
- Air-drop rendezvous
- Surveying
- Medevac
- Night patrols

2.4.4 Physical Description. The Position Locator is packaged in two containers, as shown in Figure 2-1. The display unit readout counters indicate the operator's present position in standard Army UTM map coordinate system units (meters). In addition to the readout counters, the display unit houses drive motors, a tuning fork oscillator, a mode selector switch, slewing switches, and a scale factor potentiometer. It is designed to be carried in the operator's pocket or in a special pouch on his harness. A three-foot cable that terminates in a quick-lock plug connects the display unit to the computer unit. The counters, mode selector switch, and scale factor potentiometer are illuminated by means of beta lights. (Beta lights are self-contained radioactive devices that will provide usable illumination for more than 12 years without external energy. The radiation level associated with these units is considered safe by the AEC.)

The computer unit houses a compass, electronic circuit cards, an inertial switch, and a battery, and is mounted on a backplate that is slotted to accommodate the harness or combat belt generally worn by combat personnel. Both units are waterproof and are designed to operate in any environmental conditions normally encountered in combat. Figure 2-2 shows the Position Locator in use.

SECTION 3

TECHNICAL DISCUSSION

3.1 THEORY OF OPERATION

3.1.1 General Approach. Operation of the Position Locator is based on repeated sensing of the user's step, resolution of the previously calibrated step length into east-west and north-south components, and continuous updating of the indicated position.

The accuracy of the resulting computation is not as dependent upon the repeatability of each stride length as it might at first seem because of the statistical cancellation of errors that occurs when a large number of random errors, each with an equal likelihood of having a positive or a negative value, are added together. It can readily be shown that if the total distance traveled is made up of a large number of step measurements, and the error in each step measurement is independent of that in any other step measurement, the total distance error is proportional only to the square root of the number of steps.

Mathematically, the expression for the total error is given as follows:

$$\epsilon = \sqrt{N} \times \sigma$$

where

ϵ = total standard error

N = number of steps

σ = standard deviation for each step.

For example, if the average step length is assumed to be 1 meter (a normal step length is approximately 0.8 meters) and the standard deviation in determining that length is ±0.1 meters, then for a 1-mile trip of 1600 steps the total standard error will be

$$\epsilon = \sqrt{1600} \times 0.1 \text{ meters}$$

$$\epsilon = 40 \times 0.1$$

$$\epsilon = 4 \text{ meters.}$$

This is, if the standard deviation in step measurement varies from +0.1 meter to -0.1 meter, many will cancel each other, and the total standard error will be only 4 meters for a 1-mile trip. A 4-meter error over a 1-mile course represents an error of only 0.25% of distance traveled. The laws of statistics further state that for the example cited, the error 95% of the time (2 sigma) will be less than 8 meters. For greater distances, the percentage of error will be less. Test data gathered during earlier programs confirm this analysis.

As a result of the foregoing analysis and the test data gathered earlier, the Position Locator instrumentation was based on a pedometer approach. In the system developed, the operator initially sets into the equipment his known average step length for the particular conditions of terrain he expects to traverse and his degree of fatigue. Test results have shown that with experience, an operator soon learns the appropriate setting to be inserted on the scale factor potentiometer for any set of conditions. During actual use, if the results as confirmed by a few check points indicate that the scale factor is incorrect (too low or too high) immediate correction can be made.

When the scale factor potentiometer is properly set, a voltage proportional to the average distance traveled is generated for each step. This signal is then resolved into its easting and northing components, converted into pulses (the number of which is a measure of distance traveled along the two cardinal directions), and eventually advances the display counters by the amount traveled.

Adjustment is also provided to compensate for the magnetic variation (declination) in the locality of operation. This adjustment, which is on the compass assembly, is simple to introduce during calibration, and should be valid over a relatively wide range of operation. For example, throughout Vietnam the variation is less than 1°.

3.1.2 System Operation. A technical discussion of the operation of the Position Locator can best be followed with reference to Figure 3-1. For each step, the walk inertial switch closes and initiates the computation cycle. The scale factor potentiometer, preset by the operator, provides a voltage, E_S, which is proportional to the operator's average step length. This voltage is applied to the resolving compass,

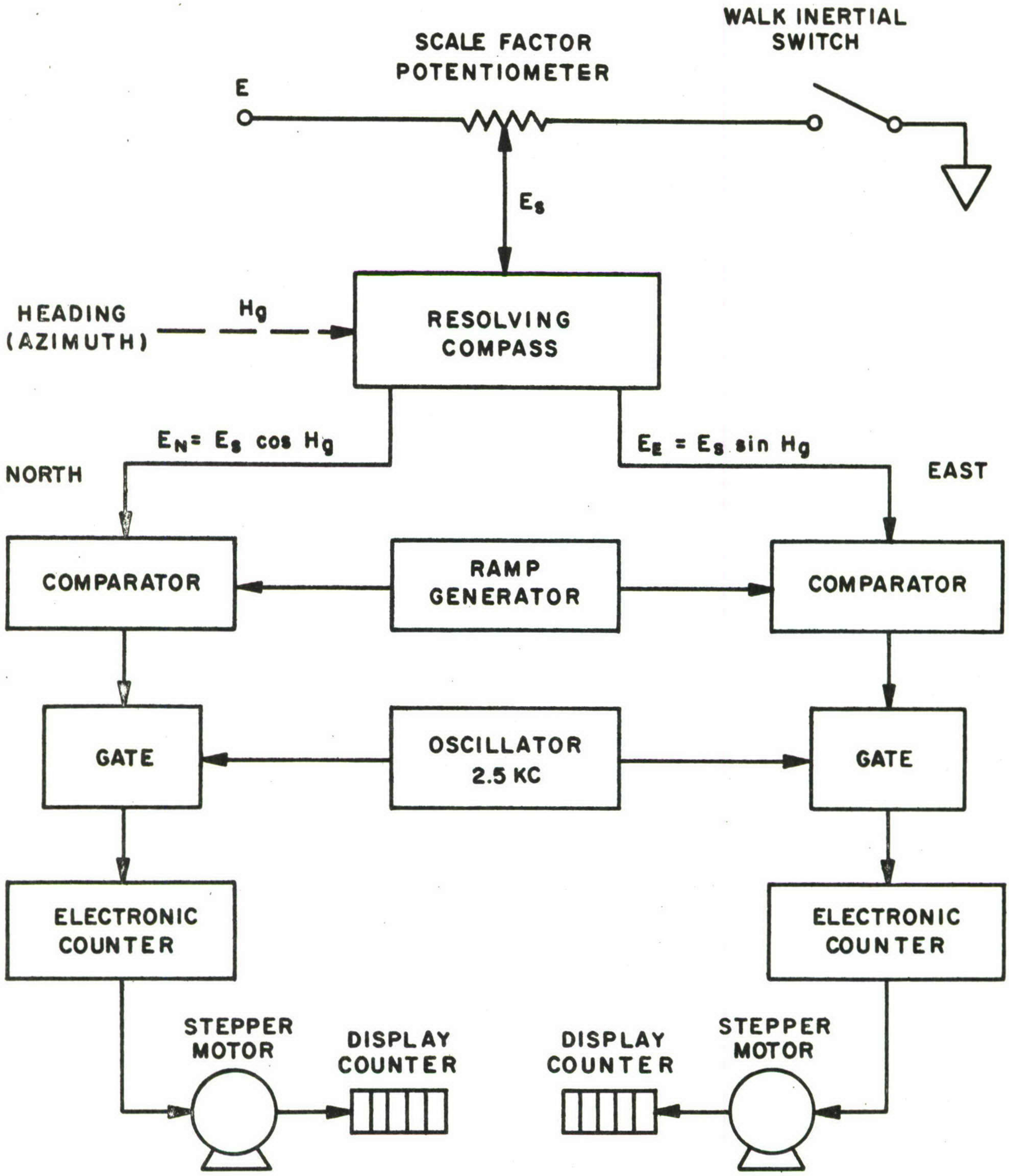


Figure 3-1. System Block Diagram

whose two outputs are proportional to the cardinal components of the direction of travel. The resolved voltages are then compared with a negative-going ramp voltage in comparator circuits that permit passage of clock pulses during the time period in which the ramp voltage exceeds the coordinate voltages (see Figure 3-2). The number of oscillator cycles or pulses that pass through each gate is determined by the "on" time of the comparator signal (t_N or t_E), and hence is a measure of distance traveled along that coordinate. A clock frequency of 2.5 kc was selected to achieve a resolution of 1 centimeter. These pulses are then divided by a factor of 500 (in stages of 10, 10, and 5) by means of an electronic counter employing integrated circuits. Each pulse corresponds to 1 centimeter of travel, or 500 pulses for 5 meters. Hence, for every 5 meters traveled in a given cardinal direction, the motor corresponding to that channel rotates one step, indexing the display counter by 5 meters.

3.1.3 Cycle Timing. Each step the operator takes activates the inertial switch, which initiates operation of the electronic circuits. The electronic circuits determine the time sequence of the operations that follow (see Figure 3-2). The compass lamps require approximately 30 milliseconds to attain full illumination. During this time the ramp and comparator output voltages are clamped to an initial value. At the end of the bulb warm-up time the comparators receive the resolved signals and the ramp signal (which also starts at this time). At the start of this cycle (the computation cycle) the outputs of the comparators are in their "on" conditions, permitting clock pulses to be delivered to the electronic counter circuits. When the ramp voltage becomes equal to or less than the resolved voltage of a particular channel, the output of that comparator returns to the "off" state, blocking the flow of clock pulses to that channel. With the end of the second comparator output (a maximum of 40 milliseconds), power to the electronic circuits is turned off (except for the storage stages). The next operator step occurs approximately 500 milliseconds later, and the process is repeated. At the maximum scale factor setting, and for a walk along a cardinal direction, the ramp voltage will intersect the compass voltage for that channel in 40 milliseconds. During this time 100 clock pulses (1 meter) will be counted.

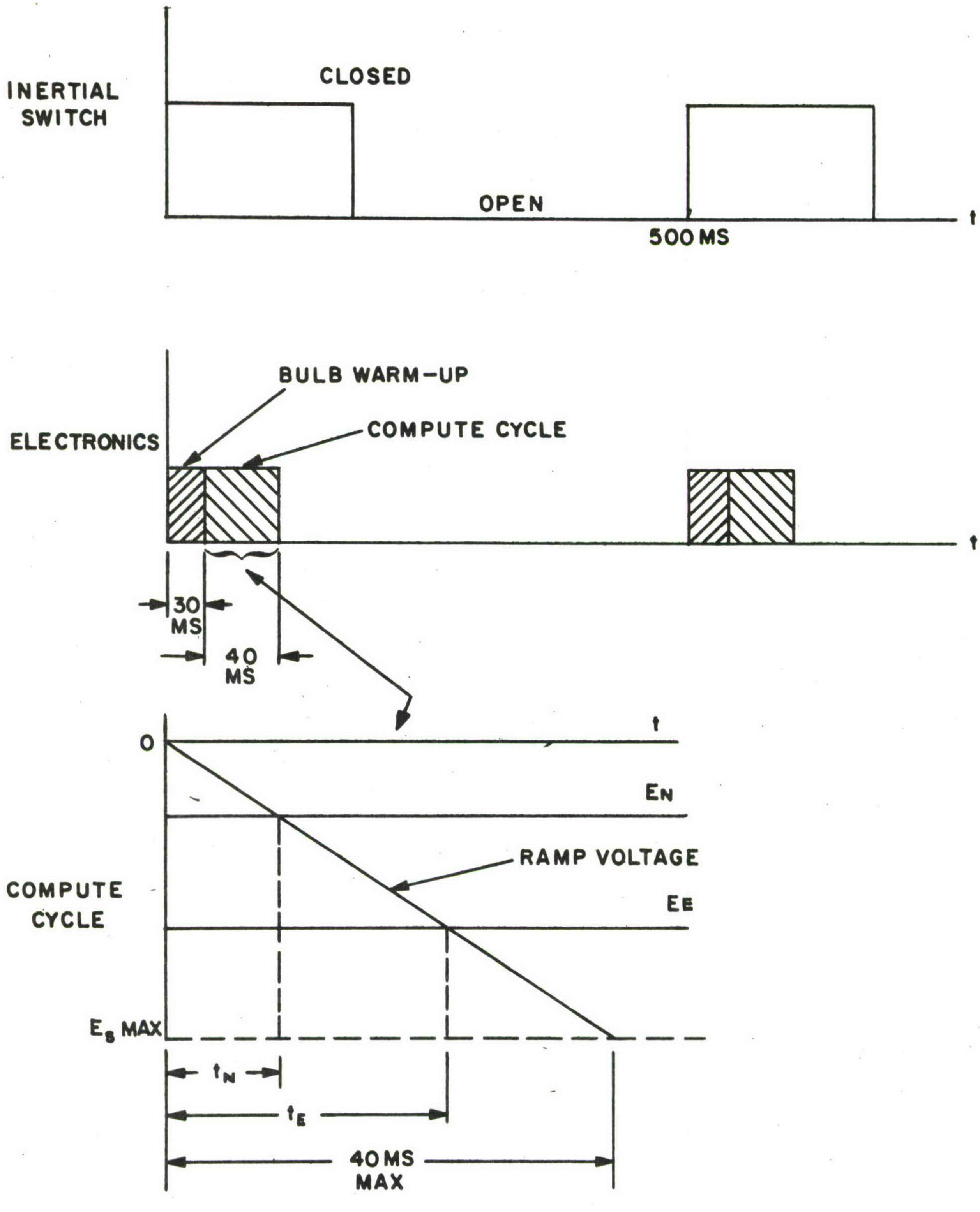


Figure 3-2. Time Sequence

When the operator is running, the computation process is similar to that discussed above except that application of the ramp voltage is modified (by closure of the run inertial switch) to prolong the time to intersection. This increases the displayed distance to 1.5 times the distance that would have accumulated for the same number of steps while walking.

The limiting of power during the actual computation phase reduces the power drain on the battery by a factor of ten.

3.2 MECHANICAL CONFIGURATION

3.2.1 Display Unit. Figure 3-3 shows the mechanical assembly of the display unit. As indicated, the two coordinate counters are mounted in a column (east indication above north) in an arrangement designed for minimum size and complexity. The scale factor adjustment potentiometer, the mode selector switch, and two slew switches are concealed under a waterproof hinged top. Electrical connection between the display unit and the computer unit is made by means of a three-foot cable that terminates in a quick-lock connector at the computer unit. The cable enters the bottom of the display unit through a waterproof seal.

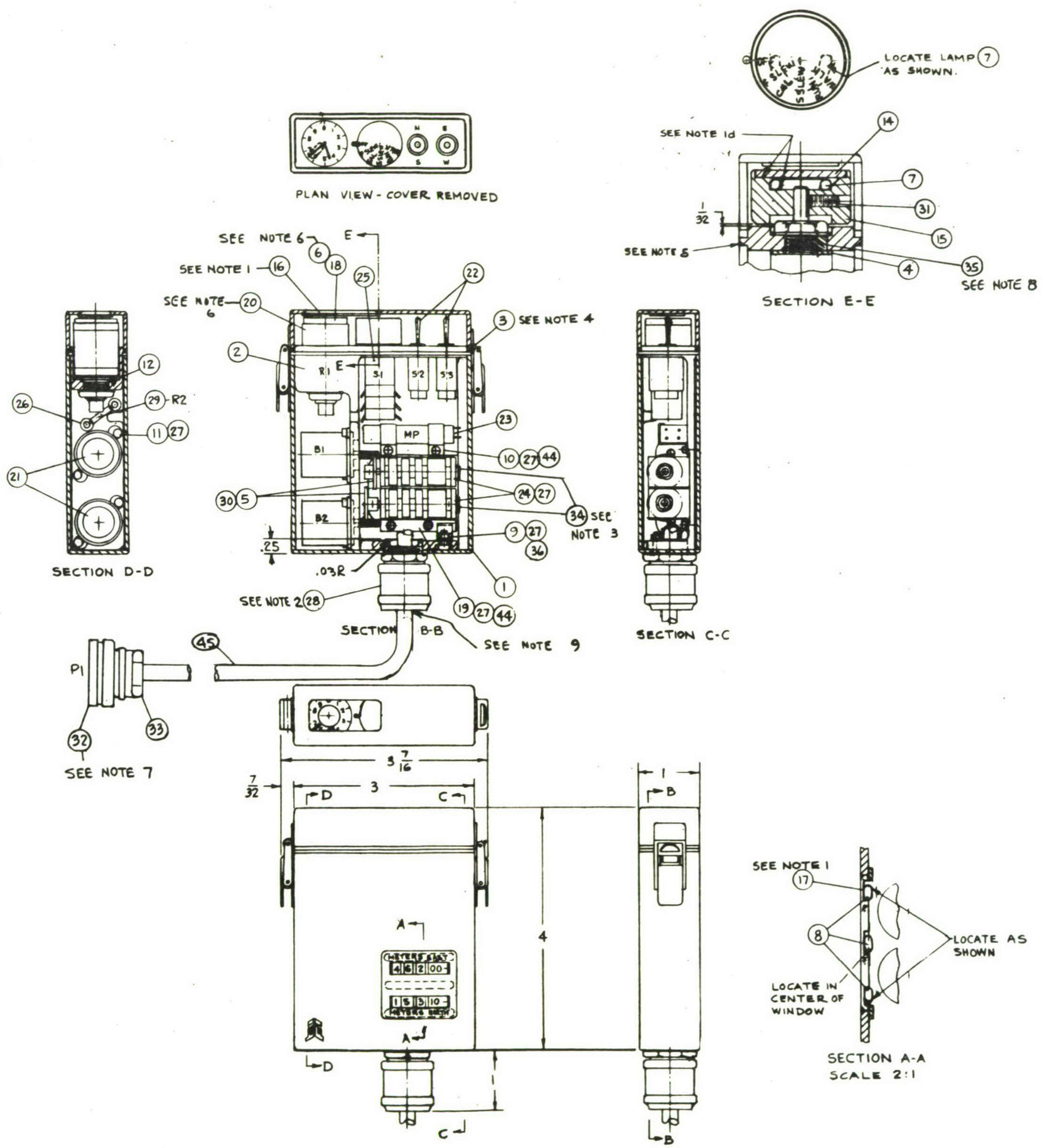
Removing the waterproof seal permits the internal assembly frame to be lifted out of the display unit case. Mounted to the frame are the two stepper motors, each geared (5:1) to its respective four wheel counters (the last wheel having a double number with reverse color markings - black numbers on white background).

Also secured to this frame are the scale factor potentiometer, the mode selector switch, two slew switches, and the tuning fork. The tuning fork is located on this unit to isolate its magnetic properties from the compass. The beta lamps are mounted on the scale factor potentiometer lens and the mask of the selector switch to provide nighttime illumination. The front mask also contains three beta lamps to illuminate the two counters.

Access to the various controls is obtained by releasing the spring-loaded clips on each side and removing the gasket-sealed top. The knob potentiometer has a 10-turn clock-like adjustment face calibrated to result in a scale factor variation from 0.5 meters per step for a reading of zero to 1 meter per step for a dial reading of 1000.

NOTES

1. USE SILICONE RUBBER (RTV) AS FOLLOWS
   a) CEMENT LAMPS TO WINDOW (SEE SECTION A-A) - 38
   b) CEMENT WINDOW TO FRAME 39
   c) FILL BEVEL EDGE OF WINDOW FOR WATER TIGHT SEAL 39
   d) CEMENT 14 AND 7 TO KNOB 15.
2. REWORK TO DIMENSION SHOWN. PAINT ONE COAT PRIMER MIL-P-8585, COLOR Y. TWO COATS OLIVE DRAB ENAMEL TT-E-52.
3. BOND SPACER 34 TO COUNTER 24 USING 41
   CAUTION: DO NOT GET ANY ADHESIVE ON SHAFT OR RETAINER RING.
4. TRIM GASKET FLUSH WITH CASE & COVER AFTER CEMENTING TO CHASSIS WITH RUBBER ADHESIVE, MIL-A-5092 TYPE II (FORD SPEC 113-095) 42.
5. SPRAY MOLD RELEASE COMPOUND ON RIM OF CASE. PLACE .005 SPACER BETWEEN INSIDE BOTTOM OF CASE AND CHASSIS. MOLD RTV (BLACK) 39 GASKET IN PLACE REMOVE SPACER AFTER RTV HARDENS
6. REMOVE EXISTING WINDOW IN KNOBPOT 20. BOND LAMP 6 IN WINDOW GROOVE 17 USING CLEAR SILICONE RUBBER (RTV) 38. ORIENT WINDOW SO THAT LAMP IS OVER LARGE HAND THEN BOND TO KNOBPOT USING 46.
7. WITH CABLE CLAMP IN PLACE POT SUFFICIENTLY USING RTV 20 40 TO SEAL PLUG AND CABLE SLEEVING.
8. BOND PIN 35 TO CHASSIS 2 USING 43.
9. TAPE CABLE TO FILL SLEEVING AT SEALING GROMMET OF 28.



FIND NO.	QTY REQD	GOVERNMENT PART OR IDENTIFYING NUMBER	FORD	NOMENCLATURE OR DESCRIPTION	FIND SYM
46		3M CO SCOTCH WELD 2216		ADHESIVE	
45	34 in			SLEEVING PVC BLACK	
44	4		202-633-2	WASHER PLAIN #2	
43	AR		113-136	ADHESIVE	
42	AR		113-095	ADHESIVE	
41	AR		113-137	ADHESIVE	
40	AR	GENERAL ELECTRIC CO	RTV 20	ORANGE SILICONE RUBBER	
39	AR		RTV	BLACK SILICONE RUBBER	
38	AR		RTV	CLEAR SILICONE RUBBER	
37					
36	1		202-635-402	NUT,	
35	1		301-622	PIN	
34	2		301-621-1	SPACER	
33	1		301-607-3	CABLE CLAMP	
32	1		301-607-2	PLUG	
31	1		202-694-419	SETSCREW, SELF-LOCKING	VD
30	2		45-055-15	PIN, SPRING	VD
29	1		IRC TYPE EM 20 TO 100 K INCL.	RESISTOR, TRIM	VD
28	1		VEMALINE PRODUCTS CO FRANKLIN LAKES N.J.	WATERPROOF CABLE CLAMP, MODEL #2000-1	VD
27	17		205-997-402	SCREW, PAN HEAD	VD
26	2		202-564-1	STUD, INSULATED	VD
25	1		401-626	ROTARY SWITCH	VA
24	2		301-584	COUNTER	VA
23	1		301-583	TUNING FORK	V
22	2		301-582	TOGGLE SWITCH	VA
21	2		301-581	MOTOR	VA
20	1		301-580	KNOBPOT	VA
19	1		301-579	SHIELD	D
18	1		301-578	LENS	D
17	1		301-577	WINDOW	D
16	1		301-576	WINDOW	D
15	1		301-575	KNOB	D
14	1		301-574	DIAL	D
13					D
12	1		301-588	GASKET	D
11	4		301-571	CLAMP	D
10	2		301-570	CLAMP	D
9	1		301-569	CLAMP	D
8	3		301-568	LAMP	VD
7	1		301-567	LAMP	VD
6	1		301-566	LAMP	VD
5	2		301-565	GEAR	D
4	1		301-590	GASKET	D
3	1		301-589	GASKET	D
2	1		501-111	CHASSIS	D
1	1		501-122	CASE ASSEMBLY	A

PARTS LIST

A = FOR SEPARATE LIST OF PARTS REFER TO IDENTIFYING NO. ASSY DWG OR ITS ASSOC PL

Figure 3-3. Display Unit Assembly

The functions initiated by the various positions of the mode selector switch are as follows:

1. OFF - This position removes all power from the instrument.

2. FAST SLEW - Fast slew permits setting the counters (via the appropriate slew switch) to their approximate settings at a speed of 250 meters per second (50 steps per second).

3. CALIBRATE - This position permits a display output that is ten times normal, or 10 meters per operator pace. The increase in resolution permits more accurate calibration of the scale factor adjustment over a shorter course.

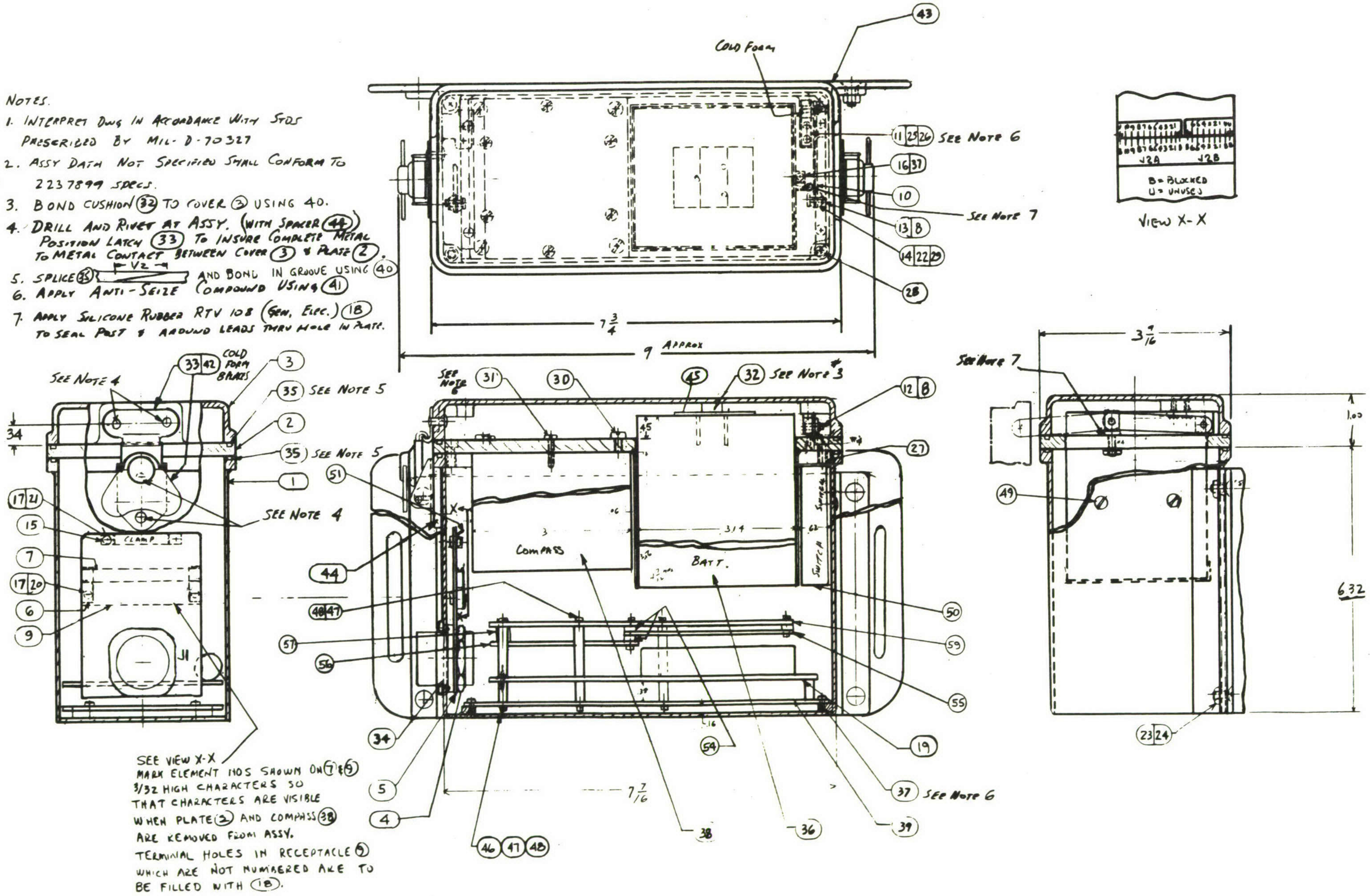
4. SLOW SLEW - This position reduces the display speed to 25 meters per second (5 steps per second), which permits a more accurate setting of initial present positions.

5. RUN - The run mode is the normal operational position. This position permits operation for both walking and running.

6. WALK - The walk mode is identical to the run mode except that the run inertial switch is omitted from the circuitry. This position was included in the experimental models to permit walk tests without the interference of the run switch should it become defective. The walk mode should be employed only when the run switch is considered unreliable.

3.2.2 Computer Unit. The assembly of the computer unit is shown in Figure 3-4. As shown, this package is suspended on a backplate designed to be secured to the operator's gun belt. Electrical connection to the display unit is made through the side connector.

Access to the compass control and battery compartment is provided by a latched watertight top cover. The compass control permits compensation insertions for magnetic declinations up to 70° east or west. A locking feature is also provided. The battery compartment will accept either a standard 45-volt carbon-zinc battery, of which there are many (Military BA-63, Eveready HO 738, Burgess No. Z-60, RCA No. VS015, and Bell System No. KS14196), or a mercury battery (SR 3693-2) especially designed for this program by the Mallory Company. Although the usable



REVISIONS

SYM	ZONE	DESCRIPTIONS	DATE	APPROVED
A		SEE ECO 21599	6/28/66	D.W.G.
B		SEE ECO 23186	17 FEB 1967	D.W.G.

FIND NO.	QTY REQD	GOVERNMENT PART OR IDENTIFYING NUMBER	FORD	NOMENCLATURE OR DESCRIPTION	FIND SYM
48	17		202-634-0	WASHER LOCK (0-80)	VD
47	12		202-630-202	SCREW	VD
46	6		301-620	POST	D
45	1		301-613	CONNECTOR	VD
44	2		301-610	SPACER	D
43	1		501-126	BAND	D
42	8		APM HEX SEAL CORP. ENGLEWOOD N.J.	APM HEX SEAL RIVET SELF SEALING 1/8 DIA x 3/16 LONG	VD
41	AR		113-070	ANTI SIEZE COMPOUND	V
40	AR		113-095	ADHESIVE	V
39	1		501-133	PRINTED BD ASSY	A
38	1		501-184	COMPASS	A
37	5	MS 16995-3		SCREW SOC. HD	VD
36	1		301-609	BATTERY	VD
35	2		301-608	"O" RING	VD
34	1		301-607-1	CONNECTOR	VA
33	2		301-606	LATCH	VD
32	1		301-605	CUSHION	VD
31	6		2566334-~~413~~	SCREW, SEAL	VD
30	4		2566334-~~420~~	SCREW, SEAL	VD
29	2	MS 35338-78		WASHER, LOCK	VD
28	4		2566334-412	SCREW, SEAL	VD
27	4	MS 21208-C0420		INSERT	VD
26	4	MS 16995-2		SCREW, SOC. HD	VD
25	4	MS 35338-77		WASHER, LOCK	VD
24	4		2437305-110	NUT, CLINCH	VD
23	4	MS 51959-45		SCREW, FLAT HD	VD
22	2	MS 35690-44		NUT, HEX.	VD
21	2	MS 51957-1		SCREW, SOC. HD.	VD
20	2	MS 51957-3		SCREW, SOC. HD.	VD
19	1		501-131	PRINTED BD ASSY	A
18	AR	GENERAL ELEC CO	RTV 108	SILICONE RUBBER	V
17	4		2437305-103	NUT, CLINCH	VD
16	1		301-604	CLAMP	D
15	1		301-603	CLAMP	D
14	2		301-602	POST	D
13	2		301-601	PIN	D
12	2		301-600	STUD	D
11	2		301-599	HANGER	D
10	2		301-598	ARM	D
9	1		301-597	RECEPTACLE, MALE	VD
8	4	MS16633-12		RING, RETAINING	VD
7	1		301-596	RECEPTACLE, FEMALE	VD
6	2		301-594	CLIP	D
5	1		301-593	PLATE	D
4	1		301-623	NUT	
3	1		501-124	COVER	D
2	1		501-123	PLATE	D
1	1		501-125	CASE	D

PARTS LIST

A = FOR SEPARATE LIST OF PARTS REFER TO IDENTIFYING NO. ASSY DWG OR ITS ASSOC PL.

Figure 3-4. Computer Unit Assembly

life of the mercury battery far exceeds that of the carbon-zinc dry cell (120 hours vs 40 hours), the carbon-zinc is preferred because of its wide availability and lower cost ($1.80 vs $45 each for small quantities).

Removal of the top mounting plate exposes the inertial switch assembly and the electronic card assembly. The electronic card assembly consists of four circuit cards (analog, digital, reset, and four single decade counters) wired to the connector. A bracket containing two smaller connectors is also included to provide connection to the compass, the inertial switches, and the battery.

The compass is secured to the bottom of the top mounting plate. Adequate seals are provided to protect the card assembly when the top cover is open.

The inertial switch assembly contains weighted arms which are displaced upward for each step. The walk switch contains a torsion spring which supports the weights to an extent that renders the switch sensitive to low accelerations. The run switch requires a higher acceleration for actuation.

3.3 FUNCTIONAL DISCUSSION

3.3.1 Inertial Switches. Figure 3-5 illustrates the two inertial switches used in the Position Locator. With each step, the walk switch is activated and starts the computation cycle. Under run conditions, the higher body acceleration causes both switches to be activated: the walk switch still controls the computation cycle, and the run switch alters the ramp time constant and hence increases the output per step.

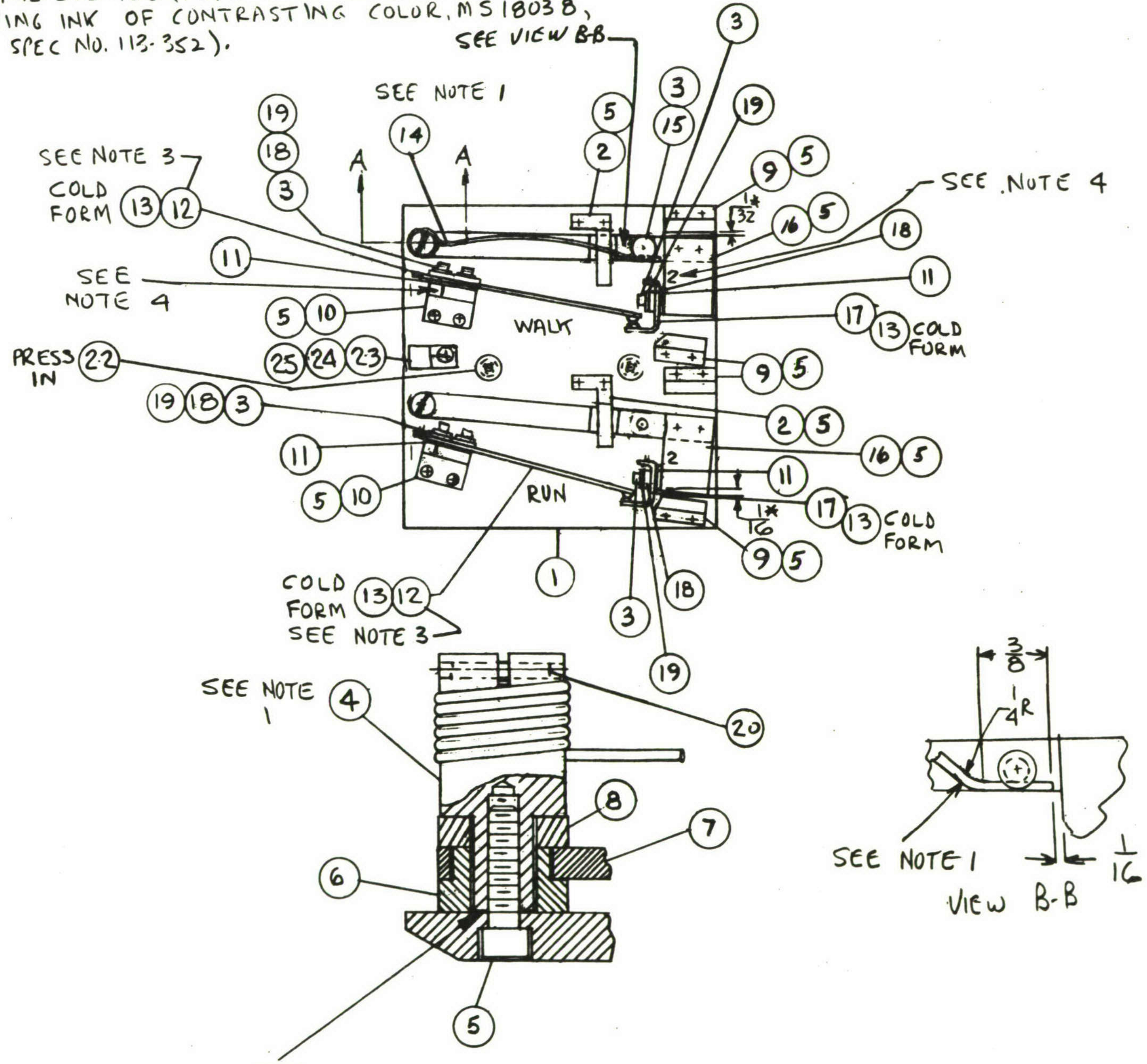
Laboratory measurements have indicated that for each step the closure time of a properly adjusted inertial switch is in the order of 150 milliseconds. For proper operation, the closure time must exceed a few microseconds and must be limited to one-half of a normal step period (250 milliseconds).

Field tests of the Position Locator have verified the reliability of the inertial switches. One unit has been activitated for over one million steps without any sign of wear or deterioration.

3.3.2 Resolving Compass. The Resolving Compass (patent pending) used in the Position Locator was originally designed by Ford Instrument Company under house funding and was repackaged for this application. Its function is to sense the operator's heading and to resolve an input voltage, whose magnitude is proportional to distance

NOTE

1. FORM SPRING TO PROVIDE STRAIGHT END PORTION IN LINE ±5° WITH PIVOT CENTER WHEN LOADED SUFFICIENTLY TO NEUTRALIZE WEIGHT. SEE VIEW B-B
2. CEMENT POST (4) TO PLATE (1) USING (21).
3. ESTABLISH * DIMENSIONS AT START OF SWITCH CLOSURE.
4. APPLY $\frac{3}{32}$ HIGH CHARACTERS 4 PLACES APPROX AS SHOWN PER MIL-STD-130 (FORD SPEC NO. 113-012) USING EPOXY RESIN MARKING INK OF CONTRASTING COLOR, MS18038, FORD SPEC NO. 113-352).



25	1		202-634-2	WASHER LOCK #2	
24	1		205-897-601	SCREW PAN HD 2-56x1/8	
23	1		301-761	CLAMP	
22	2		2437305-103	CLINCH NUT	
21	AR		113-136	ADHESIVE, EPOXY	
20	1		45-055-13	PIN, SPRING	
19	8		MS15795-801	WASHER, FLAT	
18	8		301-744	BUSHING	
17	2		301-747	CONTACTOR, RIGID	
16	2		301-745	WEIGHT	
15	1		301-751	STOP, SPRING	
14	1		301-749	TORSION SPRING	
13	4		49-281	BRUSH CONTACT	
12	2		301-746	LEAF CONTACTOR	
11	4		301-742	INSULATOR	
10	2		301-743	BRACKET	
9	4		301-752	BUMPER	
8	2		301-738	THRUST BEARING	
7	2		301-740	ARM	
6	2		301-750	BEARING	
5	24		202-693-602	SCREW, 0-80x3/16 SELF LOCK	
4	2		301-739	POST	
3	8		202-693-603	SCREW 0-80x1/4 SELF LOCK	
2	2		301-748	GUIDE	
1	1		301-741	PLATE	
FIND NO.	QTY REQD	GOVERNMENT PART OR IDENTIFYING NUMBER	FORD	NOMENCLATURE OR DESCRIPTION	FIND SYM

PARTS LIST

A = FOR SEPARATE LIST OF PARTS REFER TO IDENTIFYING NO. ASSY DWG OR ITS ASSOC PL.

Figure 3-5. Inertial Switch Assembly

traveled, into cardinal direction components. An alnico magnet attached to a floating conical card assembly positions the assembly with respect to the magnetic north pole. The card assembly, supported by jewel bearings, contains a mask which permits passage of a beam of collimated light onto a photopotentiometer such that the output voltage is a trigonometric function of the angular position of the mask assembly. The output of the photopotentiometer is directly proportional to the reference voltage and the position of the light bar. Hence, since the position of the light bar is a trigonometric function of the position of the mask assembly, the output of the photopotentiometer is likewise a trigonometric function.

The photopotentiometer is a light-actuated contactorless potentiometer consisting of a strip of high-resistance conducting plastic separated from a low-resistance collector by a narrow strip of photoconductive material (notably cadmium selenide or cadmium sulfide). In the area of illumination the resistance of the photoconductive material decreases from essentially an open circuit (10^{10} ohms) to a low resistance (10^3 ohms). For light intensity above some minimum value, the low resistance of the illuminated section of the photoconductor is essentially constant and is not affected by changes in the illumination intensity.

In addition to the two photopotentiometers, two light-sensitive silicon-controlled rectifiers (photo SCR's) are used to sense a light bar on the mask assembly and establish the particular quadrant of operation.

Illumination is provided by two miniature lamps (one for each channel), each rated for 5 volts, 75 milliamperes, and providing 0.09 candle power of light. The use of this low intensity light was made possible by including a parabolic reflector to concentrate a good percentage of the light output into a narrow strip. The reflector provides parallel rays to minimize distortion errors.

The entire compass assembly is gimbaled to ensure proper alignment to the local vertical. A heavy viscous fluid (12,000 centistokes) surrounds the compass assembly to provide damping against lateral motion caused by walking.

Separate investigations into light sources, photopotentiometers, and photo SCR's are discussed in Section 3.4.

3.3.3 Power Source. All power for the Position Locator is supplied by the standard 45-volt carbon-zinc dry cell. A series voltage regulator was designed to extend the usable range from 45 to 24 volts. The average current drain is 21 milliamperes, with a peak load of up to 500 milliamperes (for a fraction of a millisecond) during each cycle. Under normal use (8 hours per day) and at moderate temperatures, the usable life of the battery will exceed 40 hours. For continuous use (24 hours per day) the battery should be replaced after 30 hours. Prolonged slewing, operation in the calibrate mode, or operation at low temperatures will normally reduce battery life.

3.3.4 Analog Card. The analog card, one of the four electronic cards used in the Position Locator, contains the power regulator circuit, the clock oscillator circuit, the comparators, directional control circuits, the motor drivers, and circuits that start the cycle, control the bulb warm-up time, and end the cycle at the conclusion of the last computation. These are all solid state circuits with primary emphasis on low power drain. Brief descriptions of the various individual circuits as shown in Figure 3-6 are given below.

3.3.4.1 Oscillator Circuit. The oscillator circuit consists primarily of a two-stage amplifier with feedback through the 2.5-kc tuning fork (located in the display unit). The circuit operates at 10 volts and provides the bias current for the reference Zener in the regulator circuit. Pulse shaping is accomplished by a third stage.

3.3.4.2 Voltage Regulator. The voltage regulator circuit is designed to provide 21 ± 0.5 volts from a battery supply ranging from 45 to 24 volts. To ensure maximum bulb life with sufficient compass illumination, the regulated voltage is adjusted for a lamp voltage of 10 volts.

3.3.4.3 Reference Circuit. Zener regulated circuits provide reference voltages of 18.6, 14.3, 10, and 6.8 volts. Since these voltages are all fed from the same power regulator, any voltage change will be proportionally reflected in all circuits and proper functional relationships will be maintained. Hence, the gating time that permits

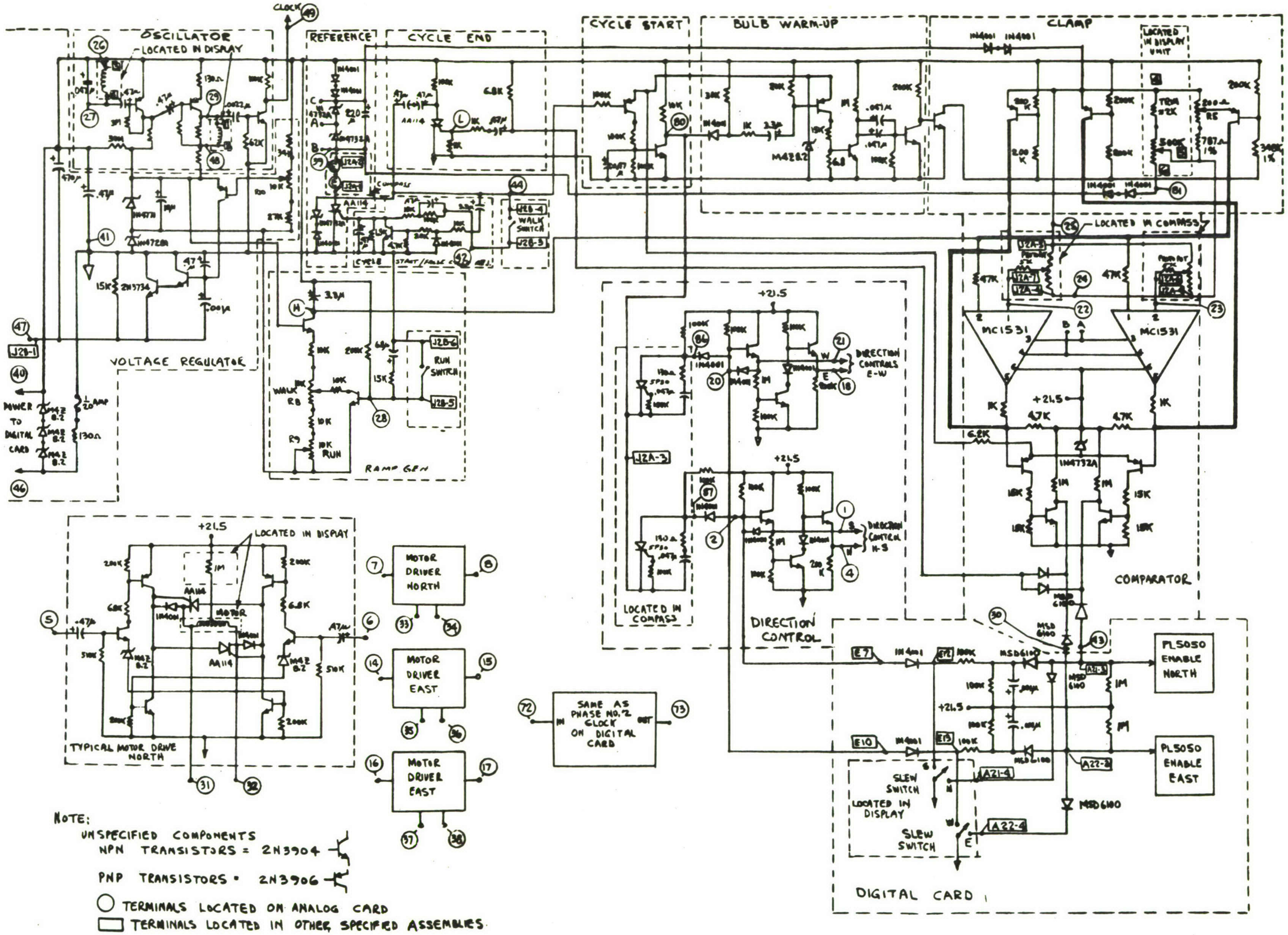


Figure 3-6. Analog Card, Schematic Diagram

passage of pulses proportional to distance traveled will also be maintained. Temperature coefficients for these circuit components have been specified to be consistent with the desired system accuracy.

3.3.4.4 Cycle Start and False-Step-Reject Circuit. The closure of the walk inertial switch applies a signal to an SCR, which initiates the start of a new cycle. Initially, double the normal excitation voltage is applied to the compass lamps, via a charging capacitor, to reduce the time required for these lamps to reach the desired intensity. Within two milliseconds, the capacitor becomes fully charged and the bulb voltage is restored to the rated 10 volts (two 5-volt bulbs in series).

For normal operation the computation time (including bulb warm-up) is in the order of 70 milliseconds, and the walk rate is one step per 500 milliseconds. In order to prevent an erroneous step indication due to contact bounce, a false-cycle rejection circuit has been added which effectively blocks out any additional switch closure that might occur within 250 milliseconds after the start of a new cycle.

3.3.4.5 Bulb Warm-Up Circuit. Following the initiation of a new cycle, the bulb warm-up circuit permits a 25- to 30-millisecond delay before the start of computation to ensure proper illumination of the photopotentiometers and photo SCR's.

3.3.4.6 Clamp Circuits. The primary function of these circuits is to maintain the ramp output voltage at its starting value until the start of the computation phase, and to hold the outputs of the two comparator circuits in the off state for the periods before and after the computation phase. This latter protection prevents any transient signal caused by normal operation of other circuits from enabling the gate circuit.

3.3.4.7 Ramp Circuit. The ramp voltage is generated by charging a 3.3 μf capacitor from a constant current source. The walk scale factor of 1 meter per step (for a maximum setting on the scale factor potentiometer) is adjusted by the current-limiting potentiometer. A second potentiometer is included to set the appropriate constant for the run mode. In the absence of a run signal, the run potentiometer is shorted by means of a transistor. A temperature-sensitive element is provided in this circuit to compensate for temperature variations.

3.3.4.8 Comparator Circuit. Each comparator circuit consists chiefly of a differential amplifier (an integrated ship) whose saturated output is dependent on the difference between two inputs. One input is the output of one compass photopotentiometer, and the other is from the ramp circuit. The amplifier output signal enables a gate circuit which permits the flow of pulses into the storage counter. As shown in Figure 3-2, the output is in the off state whenever the photopotentiometer signal exceeds the ramp value.

Prior to the start of the computation phase, the ramp voltage is maintained at its starting level and the output of the comparator is clamped to off. At the start of the computation phase, the output clamps are released. Since the starting level of the ramp voltage exceeds the voltage level from the photopotentiometer, the comparator output enables the gating of pulses. At the instant that the ramp voltage level falls below that from the photopotentiometer (the polarity is such that as the capacitor charges, the ramp voltage level decreases) the comparator switches to the off state in less than a pulse width.

Diode gating, in an AND configuration, monitors the outputs of both comparators, and causes the computation cycle to end when both comparators return to the off condition.

3.3.4.9 Direction Control Circuits. The storage of 5 meters of travel in digital form necessitates the use of an up-down counter. This in turn requires the excitation of two separate lines in accordance with the quadrant of operation. The direction control circuit receives a heading (azimuth) indication from a photo SCR on the compass, and supplies the necessary directional information. Hence, each segment of information representing 1 meter of travel directed to the 5-bit counter has associated with it the direction of travel; positive for east or north or negative for west or south.

3.3.4.10 Motor Driver Circuit. The motor driver circuit is responsible for delivering power to the stepper motor in a most efficient manner. Stepper motors contain two center-tapped windings placed at right angles (electrically) to each other. To step the motor one increment of 90 degrees, it is necessary to energize either one half of the next adjacent winding or, if proper polarities are observed, the full winding. Since the latter is the more efficient method, it is employed.

The signal that excites the motor driver circuit is derived from the output of a flip-flop and as such is continuously on until the next change of state (5 meters of travel). To conserve power, the input is transformed into a pulse of 40-millisecond duration, which is sufficient to drive the motor. SCR's are included in each stage for arc suppression.

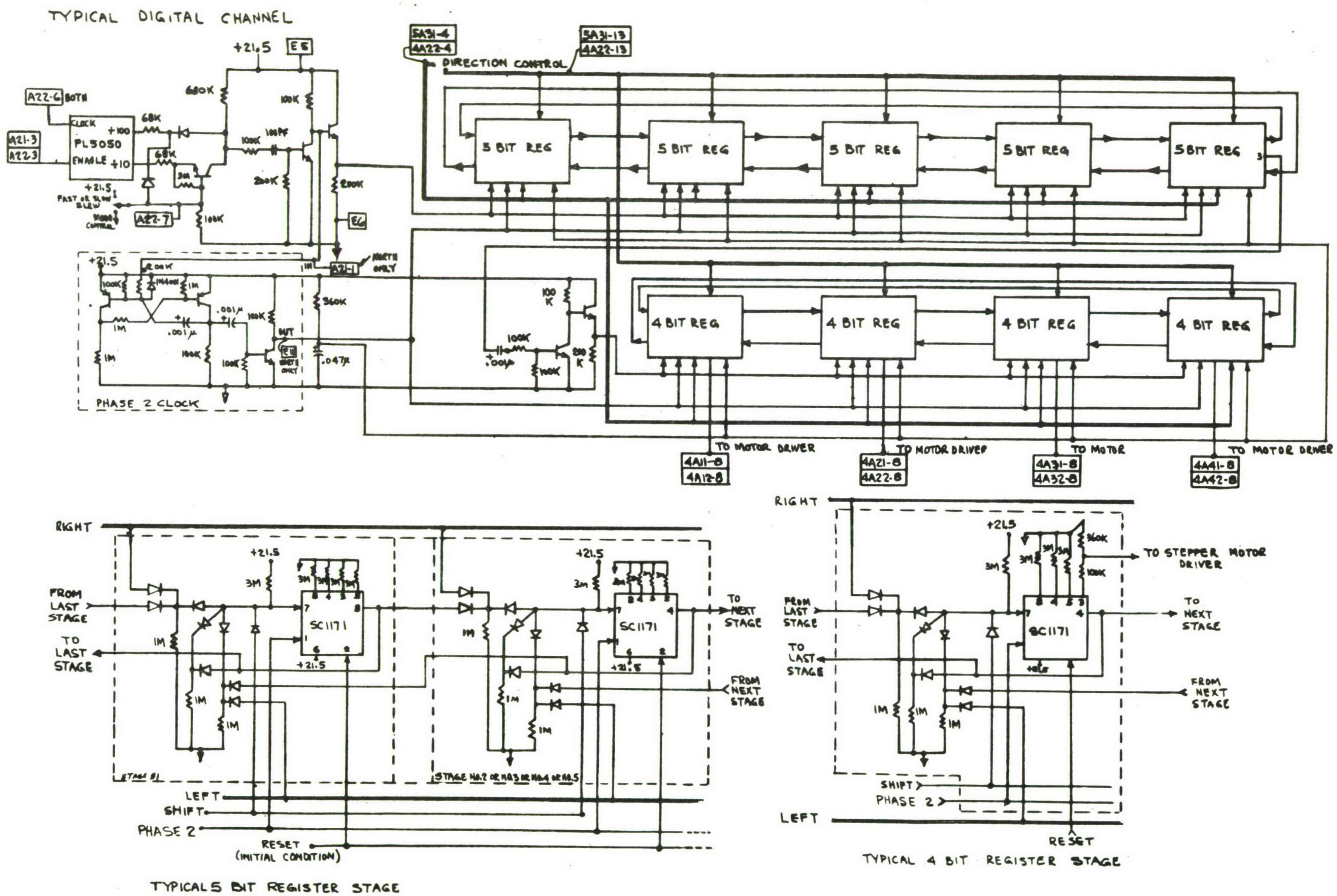
3.3.5 Digital Card. The digital card, a schematic of which appears in Figure 3-7, contains the electronic storage elements required to count the 500 pulses discussed previously.

In essence, the digital counting scheme provides the interface between a computing circuit that employs a relatively high frequency clock (2.5 kc) to obtain the required resolution, and a readout mechanism (stepping motor) that is limited to relatively low frequency response (50 cps). Driving the stepper motor at this low rate assures reliable operation over the specified temperature range, and permits utilization of some power saving techniques.

Each channel contains a dual decade counter, a 5-bit shift register, a 4-bit shift register, and the necessary interface circuits. The 5-bit shift register is designed as an up-down counter. The 4-bit shift register is used to energize the appropriate motor driver circuit in the proper sequence.

For each 100 pulses received by a dual decade unit, 1 pulse is delivered to the associated 5-bit shift register. Four of the 5 stages are at logical 0 and one stage is at logical 1. With each input pulse, the logical 1 is transferred either up or down, depending on the direction of travel, by one stage. With the fifth input to the 5-bit shift register (500 pulses into the dual decade) the logical 1 is returned to its original position, and a pulse is delivered to the 4-bit shift register. The higher scale factor (500 pulses per motor step) is used for the walk, run, and slow slew modes. For calibrate or fast slew, one decade is by-passed, resulting in motor excitation for every 50 pulses.

3.3.5.1 Dual Decade. The circuit responsible for the storage of 100 pulses originally contained a dual decade counter on a single chip, manufactured by General Microelectronic Corp. Part No. PL5050. This unit was selected for its low power consumption (30 mw), low cost, and minimum assembly requirements. During the



NOTE:

1. A21- DENOTES NORTH CHANNEL
   A22- DENOTES EAST CHANNEL

2. 5A31- DENOTES 5 BIT SHIFT REGISTER, NORTH
   4A22- DENOTES 4 BIT SHIFT REGISTER, EAST

3. SYSTEMS 1,2,4 & 5 DO NOT EMPLOY PL5050
   SEE DRAWING NO. 501 188

ALL DIODES ARE MSD 6100

ALL NPN - 2N3904

ALL PNP - 2N3906

Figure 3-7. Digital Card, Schematic Diagram

course of the program, however, it was discovered that the manufacturer could not supply these items in sufficient quantity, and it became necessary to replace these units with two single decade units (GME PL4C01). The high power requirement for each decade (120 mw) necessitated the use of a power switching circuit which applies power at a 5-kc rate at a duty cycle of 25%. This scheme permitted reduction of power from a total of 480 mw to 120 mw.

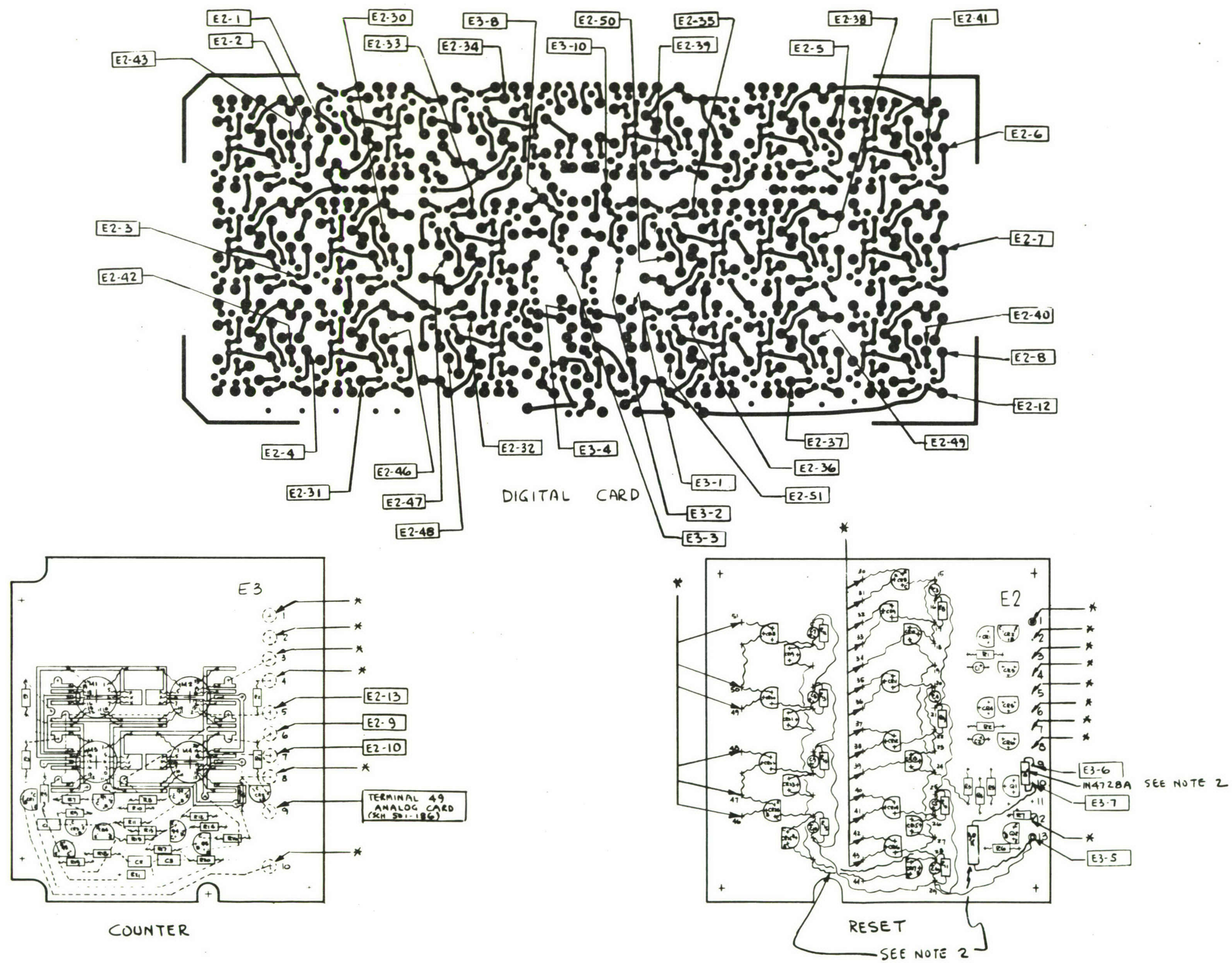
The five units delivered all contain single decade units except Serial No. 3, which still contains the original PL5050.

3.3.5.2 Five-Bit Shift Register. The 5-bit shift register consists of five stages, each stage containing one master-slave flipflop (MOS-FET) integrated circuit (GME No. SC1171) with the necessary gating. While this circuit performed as expected, it was susceptible to jam-up under certain transient conditions. At the instant of transfer of the logical 1 from one stage to the next, it is possible for a noise or transient spike to cause the transfer of the logical 1 in both the up direction and the down direction, resulting in either two logical 1's or loss of information. Two 1's would result in twice the count, while a loss of the logical 1 would cause a complete lock-up.

The solution to this problem was to monitor each stage for either possibility (multiples or absence of the logical 1) and to effect a reset (clearing all stages but one) of the 5-bit shift register. This approach has resulted in quite adequate performance.

3.3.5.3 Four-Bit Shift Register. The 4-bit shift register is identical with the 5-bit shift register except that the logical 1 energizes a corresponding input of the motor driver circuit. As before, a monitor and reset correction circuit is provided to prevent lock-up.

3.3.6 Reset Card. The reset card contains 16 gates that monitor the 4- and 5-bit shift registers for both channels and supply reset commands when necessary. Figure 3-8 is a schematic diagram for both the single decade counter and the reset circuit.



NOTE:
1. * DESIGNATES CONNECTION TO DIGITAL CARD (SCH 501-187)
2. THE COMPONENTS AND JUMPER SHOWN ARE TO BE ADDED.
3. COUNTER CARD USED ON SYSTEMS NO 1, 2, 4, 5

Figure 3-8. Single Decade Counter and Reset Circuits, Schematic Diagram

3.4 DEVELOPMENTS OF UNUSUAL INTEREST

3.4.1 <u>Battery Investigation.</u> Originally, it was proposed to use rechargeable silver-zinc cells in the Position Locator. Such advantages as maximum watt-hours per size and weight plus rechargeability made the silver-zinc an obvious choice. During the early stages of the program, however, the corrosive nature of the outgasses produced during charge and discharge of these cells placed added severe restrictions on packaging. Special attention had to be given to the case material, sealing techniques, and venting. From an electrical point of view, unique and expensive approaches were required to monitor the state of charge and to permit field recharging of the cells.

One approach to monitoring the state of charge of the silver-zinc cells was to use an ampere-hour indicator manufactured by the Curtis Instrument Company. Since the state of charge of these cells is affected by temperature, shelf life, rate of discharge, and the number of recharges, a rather complex system was required.

Charging the silver-zinc cell also introduces some unique problems. To avoid overcharge (which could shorten life) a particular terminal voltage, which is a function of temperature and charging rate, must not be exceeded. Also, to take advantage of the charging properties, automatic equipment had to be designed and made available to field units.

By some unique techniques, power consumption was reduced from the original 4 watts to 0.4 watts. This reduction in power made possible the use of other power sources. A mercury cell that would last more than 100 hours was designed by the Mallory Company (SR 3693-2) especially for this application.

A standard 45-volt carbon-zinc battery was investigated and found adequate to meet the requirements of this application. The military version for this cell is the BA63, and the specification for it does not include any mention of magnetic material. It is therefore the option of the manufacture to encase or strap the individual cells with any suitable material. Since standard batteries may employ magnetic material, dry cells to be used in the Position Locator must be checked prior to use.

Life tests were performed on a standard 45-volt cell. Figure 3-9 shows the discharge pattern under various conditions. As indicated, the battery should be replaced after 30 hours of continuous use. For normal use (less than 24 hours per day) the life of a fresh battery should exceed 40 hours.

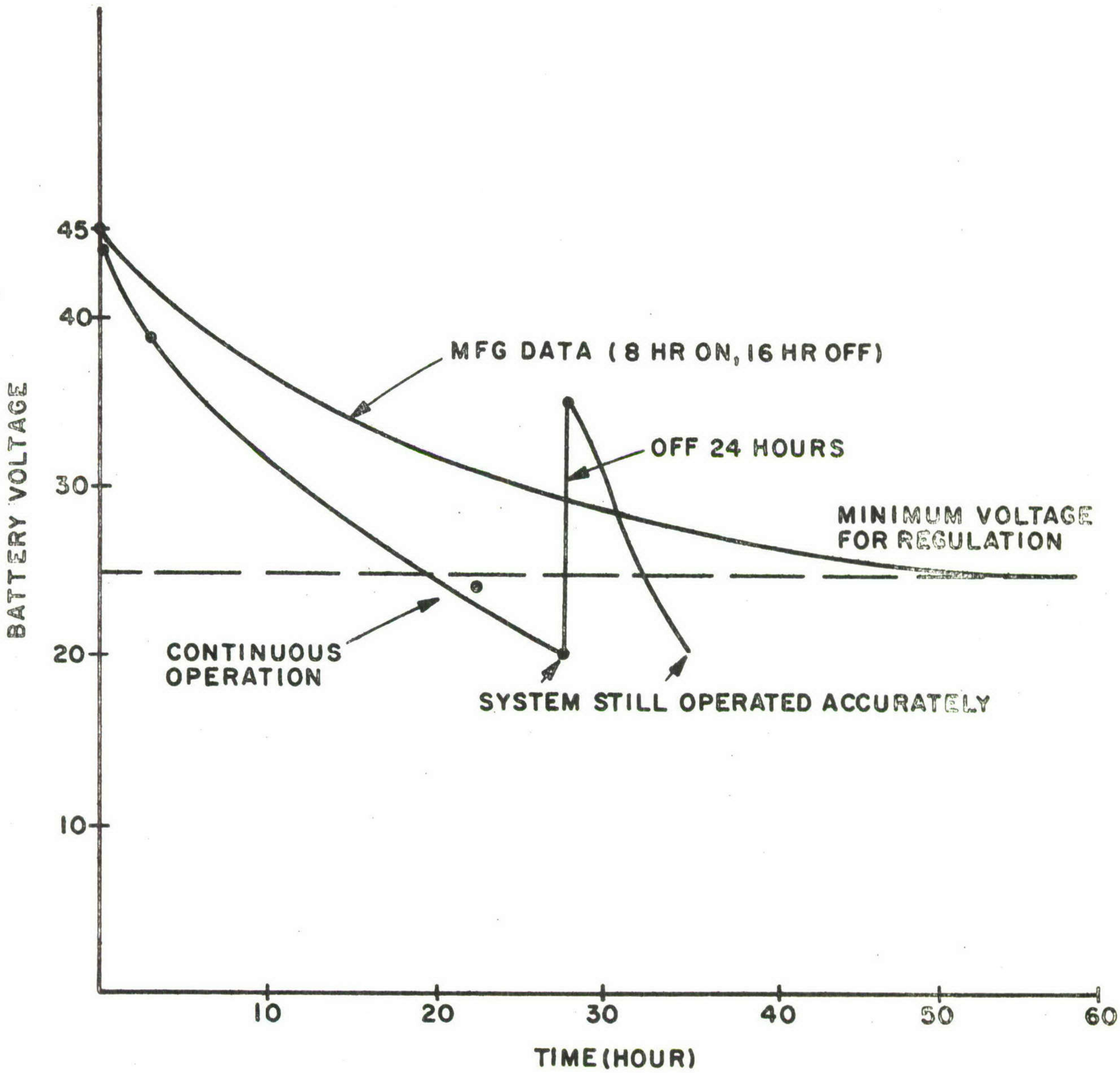


Figure 3-9. Battery Life Characteristics

3.4.2 Lamp Investigation. Illumination of the two photopotentiometers and the two photo SRC's is essential to the operation of the resolving compass. The manufacturer recommends a light bar of 0.020 to 0.030 inches with a minimum light intensity of 400 foot-candles. The geometry of the resolving compass is such that the lamp cannot be placed any closer than 7/16 inch from the photopotentiometer. At this distance the required light output would be approximately 0.54 candle power. Lamps of this intensity are relatively large in comparison with the space available and they require excessive power.

Considerable attention was given to this problem. It was first established that by proper design of the comparator circuit, a higher photopotentiometer wiper resistance could be tolerated, thus lowering the light intensity requirement. To increase the illumination efficiency, a double parabolic reflector was designed that produced a thin line beam which increased the intensity by a factor of three.

From a power standpoint, it was desirable to use a low current bulb intermittently. The computing system was modified to require a photopotentiometer output for less than 10% of the time (40 milliseconds out of a 500-millisecond period). Typical times required for bulbs to attain 90% of steady-state illumination are in the order of 100 to 200 milliseconds (see Figure 3-10). Two techniques, overvoltage and steady-state bias, were investigated to minimize bulb warm-up and hence power consumption. Figure 3-10 illustrates the improvement in warm-up time obtained with the overvoltage approach.

These various factors (light intensity, bulb size, parabolic reflector design, computation time, bulb warm-up time, and minimum power) all interrelated, had to be considered together. Large bulbs represent high power consumption and long warm-up time and packaging problems, while smaller bulbs provide insufficient light.

The final design employs two (one for each channel) 5-volt 75-milliampere bulbs, each with an output of 0.09 candle power. The circuit energizing the two series bulbs supplies an initial overvoltage of 20 volts via a 220μf capacitor charge circuit which drops to its steady-state value of 10 volts within 2 milliseconds.

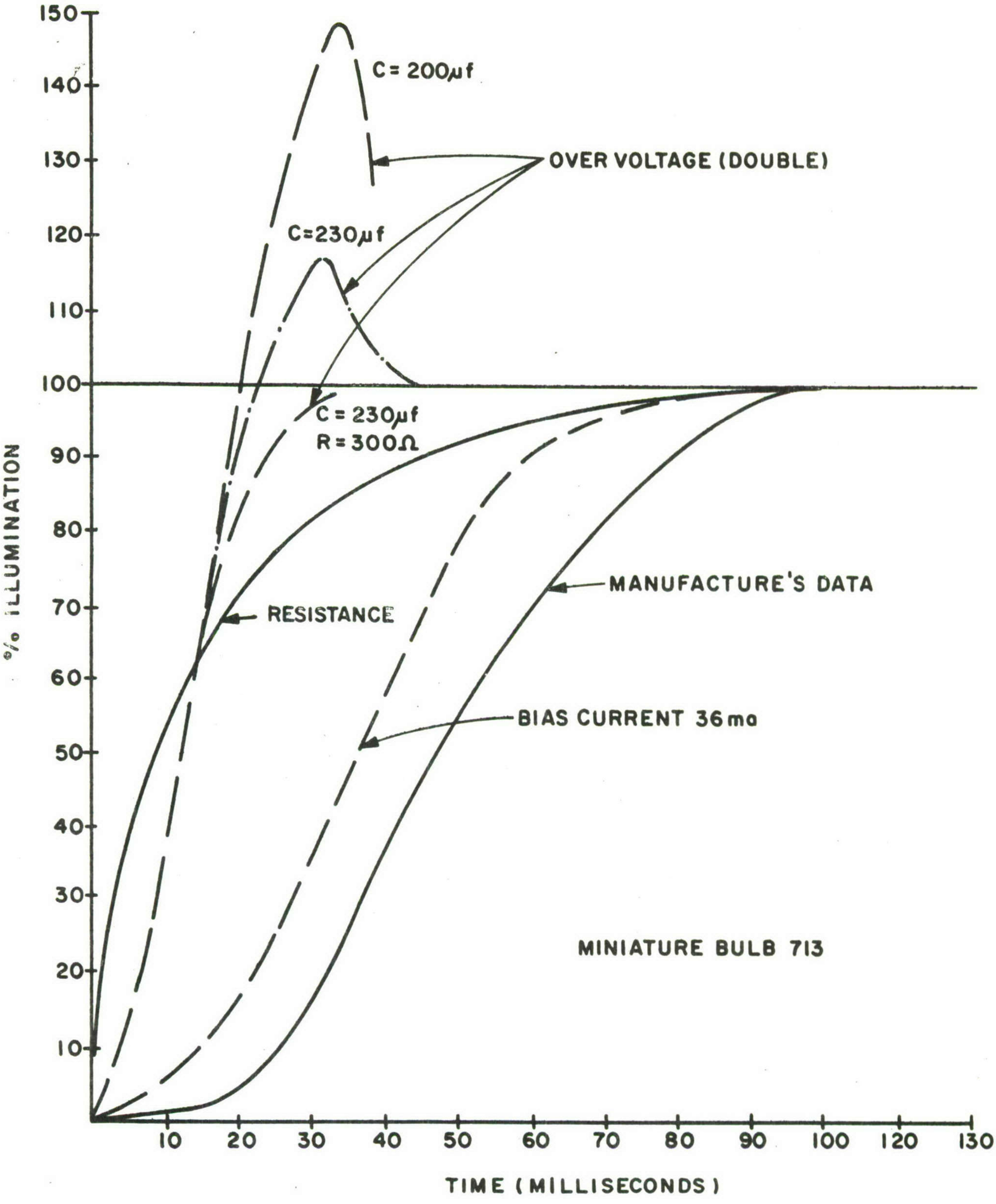


Figure 3-10. Bulb Warm-Up Period

The discharge time was selected so that the light intensity (proportional to filament temperature) never exceeds the rated value. Operated in this fashion, the expected bulb life exceeds 100,000 hours.

3.4.3 Photopotentiometers. The use of photopotentiometers as compass pickups presented two problems. To achieve linearity of better than 1%, the relatively high (5K to 10K) wiper resistance of the photopotentiometer requires a corresponding high load resistance, exceeding 1 megohm. The resulting circuitry used in the Position Locator permits changes of wiper resistance from 5K to more than 50K without loss of the required linearity.

The more serious problem results from loss of linearity at both ends of the potentiometer. The manufacturer can guarantee a linearity of 0.5% over only 70% of the potentiometer. The present design incorporates two trim potentiometers to establish the trigonometric 0 and 1 levels within the linear range.

3.4.4 Photo SCR's. Quadrature is sensed by means of a 180-degree light bar on the mask assembly and two photo SCR's mounted on the compass. All suitable devices considered for this application contained leads of Invar (a nickel alloy) material. Because of the magnetic influence of this material on the compass, photo SCR's had to be fabricated at Ford, using the basic chip. Nonmagnetic leads are bonded to the chip with a low-resistance epoxy. These units exhibit comparable characteristics except at low temperature (below 20°F).

3.5 ENVIRONMENTAL TESTS

Original plans called for environmental tests of one unit to include temperature, shock, and vibration. With the approval of the project officer, this plan was changed to omit the shock and vibration testing and to perform temperature tests on all five units. The decision was supported by the fact that two units were subjected to a considerable amount of shock and vibration during field tests at Aberdeen and Fort Benning.

The temperature tests revealed the sensitivity of the photo SCR's at temperatures of 20°F and below, and a positive change in scale factor in the order of 10% over a 100°F range (20°F to 120°F). This dependency of scale factor on temperature was improved by better than a factor of two by removing the temperature-sensitive element in the ramp generator circuit.

SECTION 4

OPERATION INSTRUCTIONS

4.1 CALIBRATION

4.1.1 General. As previously discussed, the Position Locator provides a compensating control for the local magnetic declination and a scale factor adjustment to suit the user's personal stride length. The following discussion outlines a procedure for determining these constants for a particular area of operation.

4.1.2 Test Course. To obtain maximum accuracy, both the magnetic declination and the scale factor adjustment should be properly set in accordance with the prevailing conditions. A test course simulating the conditions of use should be established. It is recommended that the test course be a square on an open field with legs of from 200 to 500 meters. As indicated in Figure 4-1, a leg or a diagonal of this course should be aligned with the local grid north.

4.1.3 Mode Selector Switch. The operator may calibrate the Position Locator, with the mode selector switch in the calibrate, the walk, or the run position. For the calibrate position, the readout is multiplied by a factor of ten for higher resolution and accuracy. Thus, if a test course leg is 200 meters, the difference in reading from the initial setting to the end of that leg will be in the order of 2000.

4.1.4 Magnetic Declination Adjustment. The magnetic declination (MAG VAR) adjustment compensates for the declination of the area of operation in addition to any bias error due to body yaw while walking. Initially, the operator inserts the value of the local magnetic declination plus any bias known from past experience. He then walks the test course (including the diagonals), traversing each leg at least twice and keeping the same scale factor setting for each leg. The angular error of each leg and diagonal (every 45°) are recorded and averaged. The average angular error is then corrected for by inserting an angular bias on the magnetic dial in the direction to cancel the error. To correct a plus (too high) azimuth error, the MAG VAR dial is turned counterclockwise. To correct a minus (too low) azimuth error, the MAG VAR dial is turned clockwise. This adjustment should be checked on the calibration course before proceeding.

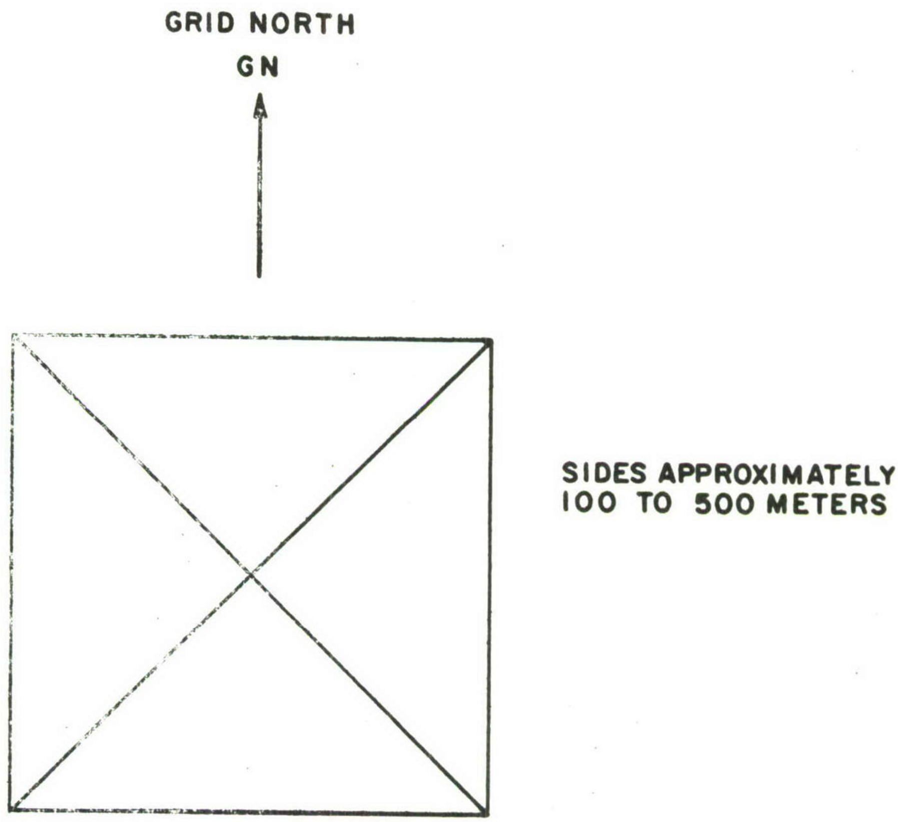


Figure 4-1. Calibration Course

4.1.5 Scale Factor Adjustment. Using the above data, the operator can easily establish whether the scale factor is on the high side or the low side of the correct setting. He should then walk one leg a number of times, changing the scale factor in the desired direction until the correct reading is obtained. Figure 4-2 can also be used to quickly determine the approximate scale factor. As illustrated in this example, if the first walk with a scale factor of 1000 produces a reading of 225 meters for a 200-meter course, and the second test produces a reading of 190 for a scale factor of 700, a line joining those two points intersects the reading of 200 for a scale factor of 800. Figure 4-3 shows some examples of scale factor readings.

4.2 MISSION PLANNING

Mission planning is considerably simplified by use of the Position Locator. There are two leading techniques presently being employed by the military for land navigation: pacing and terrain recognition.

The pacing method requires knowledge of the number of steps taken by an individual for each 100 meters. The navigator then plots his intended course in legs not exceeding 500 meters and at convenient headings. It is essential that each leg start and end with a distinguishable terrain feature or landmark. Thus a 10-mile mission may have 30 or more legs, not all in a straight line. It is also necessary for the navigator to count his steps (a 500-meter leg may require more than 600 counts) and to establish and maintain the proper headings. In navigating to a particular point on a road or stream, the individual is taught, he must introduce a heading bias in such a manner as to ensure intersecting that road or stream to the left or right of the desired point, and then proceed to the area of interest.

For areas with distinct terrain features, the individual is taught to navigate by identifying obvious landmarks (hills, streams, roads, clearings, etc.) as presented on a map.

With the Position Locator, mission planning is reduced to simply obtaining the initial coordinates and the coordinates of the destination. Route leg lengths are unlimited. Exact headings are no longer necessary since the unit continuously displays present position coordinates. Desired or emergency departures from an intended route are conveniently handled by the Position Locator, without the need of recharting or any other instrument adjustment.

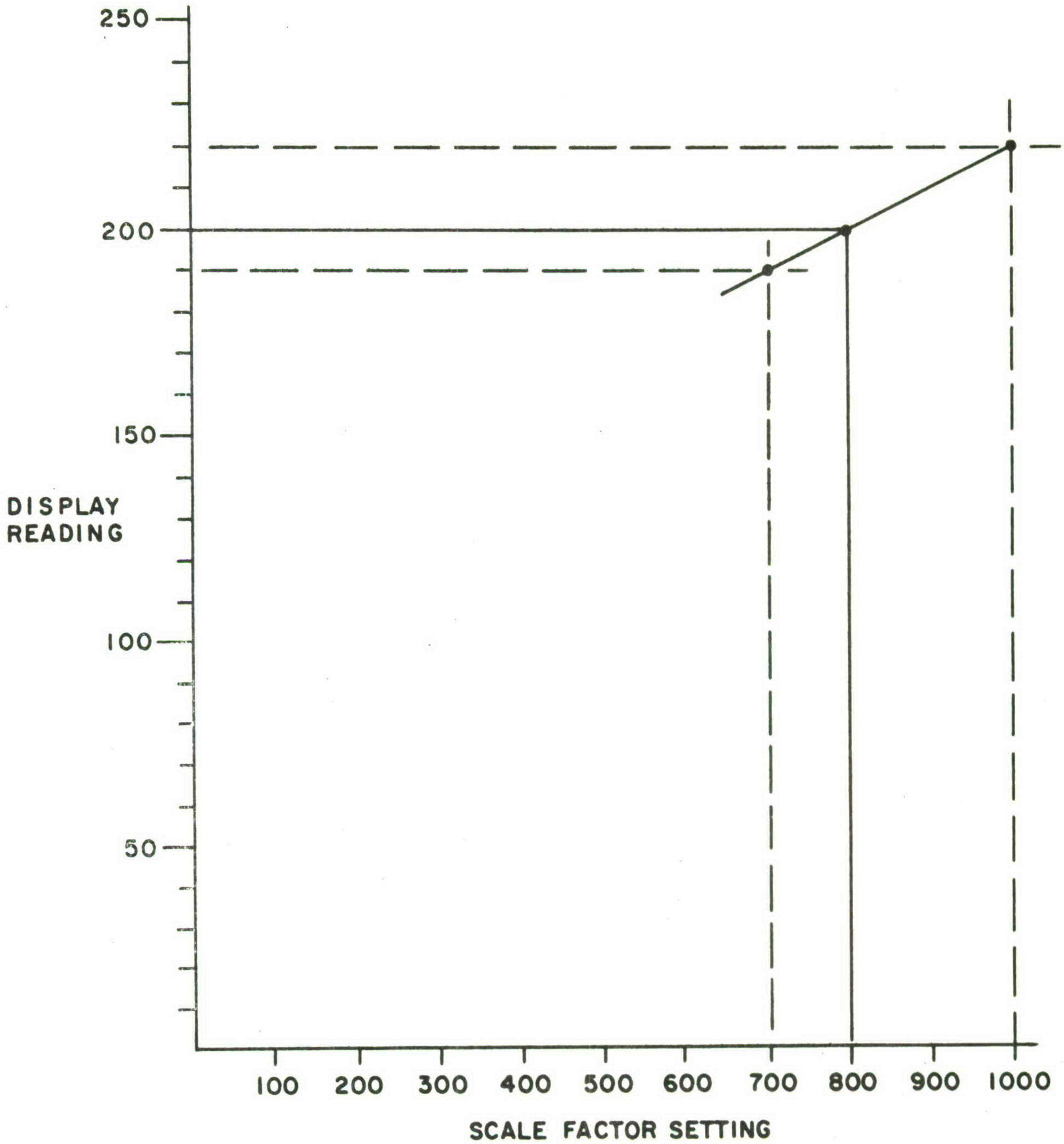


Figure 4-2. Scale Factor Curve

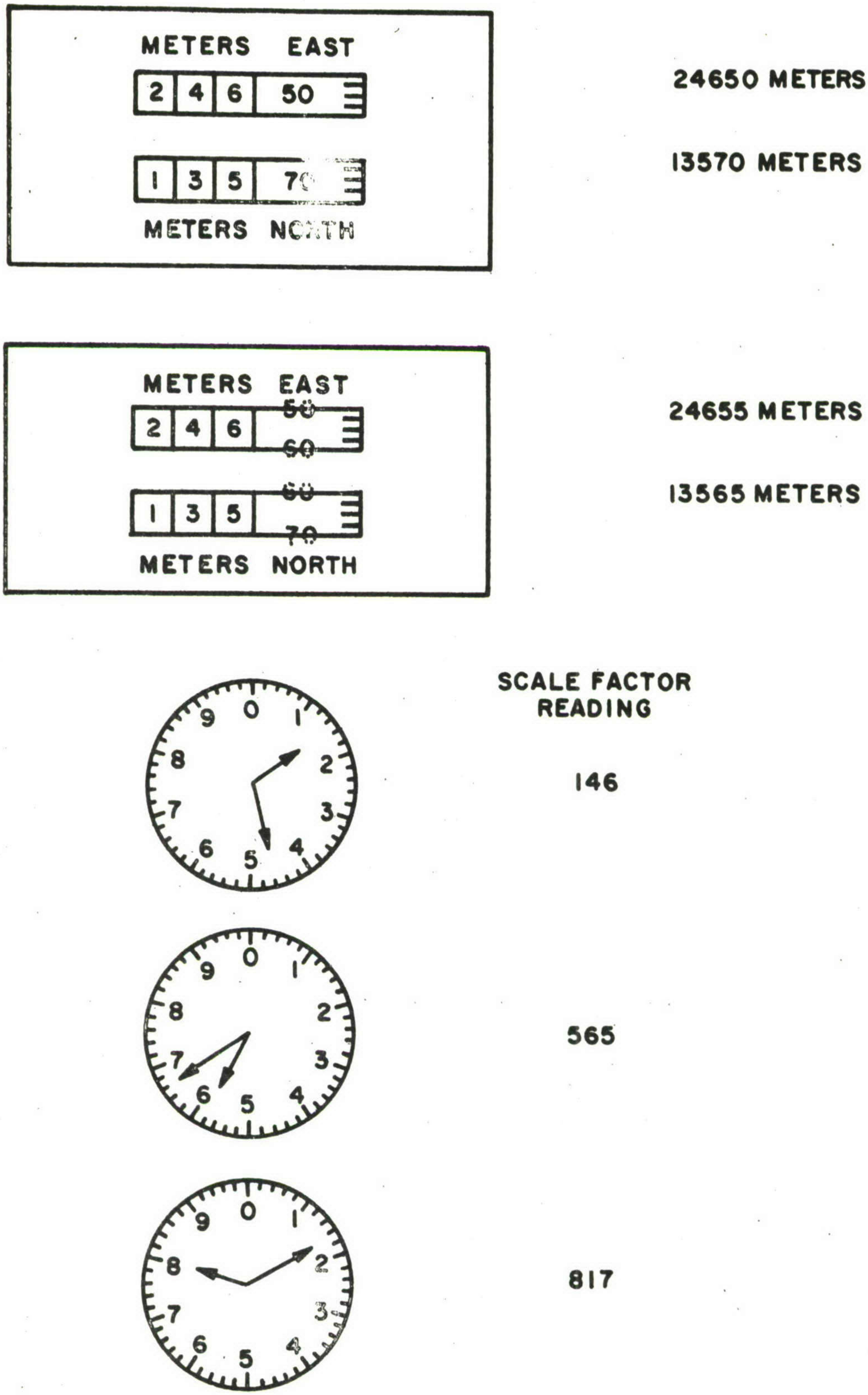


Figure 4-3. Typical Display Readings

4.3 MISSION USE

4.3.1 General. On the basis of numerous discussions with the project officer and field users, it is anticipated that individuals will be trained in the operation of the Position Locator as part of a basic or advanced training course. Experience with the first five units suggests a training cycle of less than 40 hours.

During actual mission use, the operator must first check the life of the battery, either from past records or with a voltmeter, as described in the operational manual. (Future models may employ an automatic battery tester.)

The operator inserts his previously determined scale factor and the appropriate magnetic declination into the instrument. The declination setting will be correct for all types of terrain within an area of constant magnetic variation.

4.3.2 Slew Switch. By means of the fast and slow slew positions of the mode selector switch and the slew switches, the operator inserts his starting or initial position coordinates into each channel. Figure 4-3 shows some typical readings.

4.3.3 Operation. The mode selector switch should be placed in the run position. The run position causes the equipment to operate for both walk and run conditions, and is the position that should be used. When the selector is in the walk position, the run inertial switch is removed from the circuit. The walk position should be used only when the intended use does not include running or when the run inertial switch is suspected of malfunctioning.

Once the instrument has been prepared in accordance with the foregoing instructions, its performance should be acceptable. For maximum accuracy, the operator should be aware of small changes in scale factor for different terrain conditions (hills, sand, grass, wooded areas, mud, etc.) and any other variable factors and make the necessary adjustment in the scale factor setting.

SECTION 5
FIELD TESTS

5.1 GENERAL

Extensive field tests and evaluations of the Position Locator have been conducted at a number of Army installations and in Vietnam under the direction of the Limited War Laboratory. It is anticipated that a full report of their findings will be available in the near future. The following sections present the intent and general results of these tests.

5.2 TESTS IN U.S.A.

Initial tests were performed by Ford Instrument Company at Nassau County Park, Long Island, New York, on a calibration course of 160 meters. These tests uncovered some shortcomings which were later rectified.

The majority of tests were conducted at Aberdeen Proving Ground in Maryland. Two Special Forces personnel were assigned to this project specifically, to become acquainted with the instrument and to conduct field tests in the States and Vietnam.

Unit No. 3 was field tested for over 1,000,000 meters (approximately 600 miles). Tests were conducted over a variety of terrain (flat grass, hills, sand, wooded areas) and included rain and snow conditions. Specific tests were performed to determine the effects of the proximity of ammunition, rifle, steel helmet, and back radio, all with satisfactory results. These series of tests were conducted during the period from October through January. The remaining four units received similar attention, to varying degrees, with equal success.

Some tests were also conducted at Fort Benning and Fort Bragg. In most cases, the average error was in the neighborhood of 1 to 2 percent.

5.3 VIETNAM

In mid-February all five units, and the two Special Forces men, were sent to Vietnam for actual combat evaluation. At the time of publication, the units had been favorably received and had performed well under some actual combat conditions. One type of failure developed due to excessive use under the high temperatures

encountered. This problem has been traced to an overstressing of the series regulator transistor and has been rectified in one unit. Repair kits with detailed instructions have been prepared and sent to Vietnam for correction of the others. It is expected that a detailed account of the Vietnam tests will be prepared by LWL.

SECTION 6

MISCELLANEOUS

6.1 FILM

As part of this program, a 16mm narrated color movie was prepared documenting the operational features and the use of the Position Locator. Specifically, this film introduces the various controls, readouts, and major assemblies, describes the system function (in block form), and illustrates tactical applications such as command and control, search and destroy, forward observer, surveying, field grouping, and medevac operations.

6.2 OPERATIONAL MANUAL

An Operational and Maintenance Manual was prepared which introduces the user to the basic operation of the Position Locator and presents procedures for the calibration and use of the instrument. Sketches, assembly drawings, schematics, and wiring diagrams are included to assist in servicing.

6.3 TRAINING

As indicated earlier, two Special Forces personnel were assigned to this program to conduct field evaluation. These men were trained both in the field and in the plant on the basic functional operation, maintenance, and adjustment of the instrument as well as field use. At present they are serving in Vietnam as instructors in the use of the Position Locator.

SECTION 7

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13. ABSTRACT

This document describes the design, development, manufacture, and field evaluation of five identical prototypes of a man-carried land navigation system. The unit, known as the Position Locator, provides the user with precise knowledge of his present position in standard Army UMT coordinates (meters).

The five units developed during this program each weigh 10 pounds, occupy 212 cubic inches, and have a battery life exceeding 40 hours. In numerous tests performed in the laboratory and the the customer's facility, accuracies in the order of 1% were achieved.

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